AIR FORCE
22.B SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) Phase I
PROPOSAL PREPARATION INSTRUCTIONS
AMENDMENT 1
13 May 2022

This Amendment hereby makes the following revisions:

1. Topic SF22B-T006 is hereby revised.

All other solicitation terms and provisions remain unchanged as a result of this Amendment.

AIR FORCE
22.B SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) Phase I
PROPOSAL PREPARATION INSTRUCTIONS

Air Force (AF) Phase I proposal submission instructions are intended to clarify the Department of Defense (DoD) Broad Agency Announcement (BAA) as it applies to the topics solicited herein. **Firms must ensure proposals meet all requirements of the 22.B STTR BAA posted on the DoD SBIR/STTR Innovation Portal (DSIP) at the proposal submission deadline date/time.**

Complete proposals **must** be prepared and submitted via https://www.dodsbirsttr.mil/submissions/ (DSIP) on or before the date published in the DoD 22.B STTR BAA. Offerors are responsible for ensuring proposals comply with the requirements in the most current version of this instruction at the proposal submission deadline date/time.

Please ensure all e-mail addresses listed in the proposal are current and accurate. The AF is not responsible for ensuring notifications are received by firms changing mailing address/e-mail address/company points of contact after proposal submission without proper notification to the AF. **If changes occur to the company mail or email addresses or points of contact after proposal submission, the information must be provided to the AF SBIR/STTR One Help Desk.** The message shall include the subject line, “22.B Address Change”.

Points of Contact:

- General information related to the AF SBIR/STTR program and proposal preparation instructions, contact the AF SBIR/STTR One Help Desk at usaf.team@afsbirsttr.us.
- Questions regarding the DSIP electronic submission system, contact the DoD SBIR/STTR Help Desk at dodsbirsupport@reisystems.com.
- For technical questions about the topics during the pre-announcement and open period, please reference the DoD 22.B STTR BAA.
- Air Force SBIR/STTR BAA Contracting Officers (CO):
  - Mr. Daniel Brewer, Daniel.Brewer.13@us.af.mil

General information related to the AF Small Business Program can be found at the AF Small Business website, http://www.airforcesmallbiz.af.mil/. The site contains information related to contracting opportunities within the AF, as well as business information and upcoming outreach events. Other informative sites include those for the Small Business Administration (SBA), www.sba.gov, and the Procurement Technical Assistance Centers (PTACs), http://www.aptacus.us.org. These centers provideGovernment contracting assistance and guidance to small businesses, generally at no cost.

CHART 1: Air Force 22.B STTR Phase I Information at a Glance

Topic Number	Performance Period	Max STTR Funding	Technical Volume Contents
AF22B-T001	9 months	$150,000	White Paper NTE 20 Pages

PHASE I PROPOSAL SUBMISSION

DoD 22.B STTR BAA, https://www.dodsbirsttr.mil/submissions/login, includes all program requirements. Phase I efforts should address the feasibility of a solution to the selected topic's requirements. See Chart 1 (AF-1) for proposal dollar values, periods of performance, and technical volume content.

Limitations on Length of Proposal

The Phase I Technical Volume page limits identified in Chart 1 do not include the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j). The Technical Volume must be no smaller than 10-point on standard 8-1/2" x 11" paper with one-inch margins. Only the Technical Volume and any enclosures or attachments count toward the page limit. In the interest of equity, pages/slides in excess of the stated limits will not be reviewed. The documents required for upload into Volume 5, "Other", do not count toward the specified limits.

Phase I Proposal Format

Proposal Cover Sheet: If selected for funding, the proposal's technical abstract and discussion of anticipated benefits will be publicly released. Therefore, do not include proprietary information in these sections.

Technical Volume: The Technical Volume should include all graphics and attachments but should not include the Cover Sheet, which is completed separately. Phase I technical volume (uploaded in Volume 2) shall contain the required elements found in Chart 1. Make sure all graphics are distinguishable in black and white.

Key Personnel: Identify in the Technical Volume all key personnel who will be involved in this project; include information on directly related education, experience, and citizenship.

- A technical resume of the Principal Investigator, including a list of publications, if any, must be included.
- Concise technical resumes for subcontractors and consultants, if any, are also useful.
- Identify all U.S. permanent residents to be involved in the project as direct employees, subcontractors, or consultants.
- Identify all non-U.S. citizens expected to be involved in the project as direct employees, subcontractors, or consultants. For all non-U.S. citizens, in addition to technical resumes, please provide countries of origin, the type of visa or work permit under which they are performing and an explanation of their anticipated level of involvement on this project, as appropriate. Additional information may be requested during negotiations in order to verify the foreign citizen's eligibility to participate on a contract issued as a result of this announcement.

Phase I Work Plan Outline

NOTE: The AF uses the Phase I Work Plan Outline in lieu of a Statement of Work (SOW). DO NOT include proprietary information in the Work Plan Outline. This will necessitate a request for revision and may delay contract award, if selected.

In the Work Plan section, start with a Work Plan Outline in the following format:

1) Scope: List the major requirements and specifications of the effort.

2) Task Outline: Provide a brief outline of the work to be accomplished over the span of the Phase I effort.
3) Milestone Schedule
4) Deliverables
    a. Kickoff meeting within 30 days of contract start
    b. Progress reports
    c. Technical review within 6 months
    d. Final report with SF 298

Cost Volume: Cost information should be provided by completing the Cost Volume in DSIP and including the Cost Volume Itemized Listing specified below. The Cost Volume detail must be adequate to enable Air Force personnel to determine the purpose, necessity and reasonability of each cost element. Provide sufficient information (a-i below) regarding funds use if an award is received. The DSIP Cost Volume and Itemized Cost Volume Information will not count against the specified page limit. The itemized listing may be submitted in Volume 5 under the "Other" dropdown option.

a. **Special Tooling/Test Equipment and Material**: The inclusion of equipment and materials will be carefully reviewed relative to need and appropriateness to the work proposed. Special tooling and test equipment purchases must, in the opinion of the CO, be advantageous to the Government and relate directly to the effort. It may include such items as innovative instrumentation and/or automatic test equipment.

b. **Direct Cost Materials**: Justify costs for materials, parts, and supplies with an itemized list containing types, quantities, prices and where appropriate, purpose.

c. **Other Direct Costs**: This category includes, but it not limited to, specialized services such as machining, milling, special testing or analysis, and costs incurred in temporarily using specialized equipment. Proposals including leased hardware must include an adequate lease vs. purchase justification.

d. **Direct Labor**: Identify key personnel by name, if possible, or by labor category if not. Direct labor hours, labor overhead and/or fringe benefits, and actual hourly rates for each individual are also necessary.

e. **Travel**: Travel costs must relate to project needs. Break out travel costs by trip, number of travelers, airfare, per diem, lodging, etc. The number of trips required, as well as the destination and purpose of each, should be reflected. Recommend budgeting at least one trip to the Air Force location managing the contract.

f. **Subcontracts**: Involvement of a research institution in the project is required. Involvement of other subcontractors or consultants may also be desired. Describe in detail the tasks to be performed in the Technical Volume and include information in the Cost Volume for the research institution and any other subcontractors/consultants. The proposing SBC must perform a minimum of 40% of the Phase I R/R&D and the research institution must perform a minimum of 30%. Work allocation is measured by direct and indirect costs AFTER REMOVAL OF THE SBC's PROPOSED PROFIT. This work allocation requirement is codified in statute; therefore, the Government CO cannot waive it. STTR efforts may include subcontracts with Federal Laboratories and Federally Funded Research and

Development Centers (FFRDCs). NOTE: Not all Federal Laboratories or FFRDCs qualify as research institutions.

Support subcontract costs with copies of executed agreements. The supporting agreement documents must adequately describe the work to be performed. At a minimum, each planned subcontractor's information must include a SOW with a corresponding detailed cost proposal.

g. **Consultants**: Provide a separate agreement letter for each consultant. The letter should briefly state what service or assistance will be provided, the number of hours required, and hourly or daily rate.

h. **DD Form 2345**: For proposals submitted under export-controlled topics, either by International Traffic in Arms or Export Administration Regulations (ITAR/EAR), a copy of a certified DD Form 2345, Militarily Critical Technical Data Agreement, or evidence of application submission must be included. The form, instructions, and FAQs may be found at the United States/Canada Joint Certification Program website, http://www.dla.mil/HQ/InformationOperations/Offers/Products/LogisticsApplications/JCP/DD2345Instructions.aspx. The DD Form 2345 must be approved prior to award if proposal is selected for negotiations and funding.

NOTE: Restrictive notices notwithstanding, proposals may be handled for administrative purposes only, by support contractors TEC Solutions, Inc., APEX, Oasis Systems, Riverside Research, Peerless Technologies, HPC-COM, Mile Two, Wright Brothers Institute, and MacB (an Alion Company). In addition, only Government employees and technical personnel from Federally Funded Research and Development Centers (FFRDCs) MITRE and Aerospace Corporations working under contract to provide technical support to AF Life Cycle Management Center and Space and Missiles Centers may evaluate proposals. All support contractors are bound by appropriate non-disclosure agreements. Please contact one of the Contracting Officer identified on A-1 with any concerns.

i. **Cost Sharing**: Cost share is not accepted as part of Phase I proposals.

Company Commercialization Report (CCR) (Volume 4)
Completion of the CCR as Volume 4 of the proposal submission in DSIP is required. Please refer to the DoD SBIR Program BAA for full details on this requirement. Information contained in the CCR will not be considered by the Air Force during proposal evaluations.

DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TABA)

The Air Force does not participate in the Discretionary Technical and Business Assistance (TABA) Program. Proposals in response to Air Force topics should not include TABA.

PHASE I PROPOSAL SUBMISSION CHECKLIST

Firms shall register in the System for Award Management (SAM), https://www.sam.gov, to be eligible for proposal acceptance. Follow instructions therein to obtain a Commercial and Government Entity (CAGE) code and Dunn and Bradstreet (DUNS) number. Firms shall also verify "Purpose of Registration" is set to "I want to be able to bid on federal contracts or other procurement opportunities. I also want to be able to apply for grants, loans, and other financial assistance programs", NOT "I only want to apply for federal assistance opportunities like grants, loans, and other financial assistance programs." Firms registered to compete for federal assistance opportunities only at the time of proposal submission will not be considered for award. Addresses must be consistent between the proposal and SAM at award. Previously registered firms are advised to access SAM to ensure all company data is current before proposal submission and, if selected, award.

1) The Air Force Phase I proposal shall follow the topic-specific information in Chart 1.

2) It is mandatory complete proposal submission -- DoD Proposal Cover Sheet, Technical Volume with any appendices, Cost Volume, Itemized Cost Volume Information, Company Commercialization Report, and Fraud, Waste and Abuse Certificate of Training Completion -- be executed electronically through DSIP.

Please note the FWA Training shall be completed prior to proposal submission. When training is complete and certified, DSIP will indicate completion of the Volume 6 requirement. The proposal cannot be submitted until the training is complete. The AF recommends completing submission early, as site traffic is heavy prior to solicitation close, causing system lag. **Do not wait until the last minute.** The AF will not be responsible for proposals not completely submitted prior to the deadline due to system inaccessibility unless advised by DoD.

AIR FORCE PROPOSAL EVALUATIONS

The AF will utilize the Phase I proposal evaluation criteria in the DoD 22.B STTR BAA with the factors in descending order of importance.

The AF will utilize Phase II evaluation criteria in the DoD 22.B STTR BAA with the factors in descending order of importance.

Proposal Status and Feedback

The Principal Investigator (PI) and Corporate Official (CO) indicated on the Proposal Cover Sheet will be notified by e-mail regarding proposal selection or non-selection. Small businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the Proposal Number and Topic Number referenced.

Feedback will not be provided for Phase I proposals determined Not Selectable.

IMPORTANT: Proposals submitted to the AF are received and evaluated by different organizations, handled topic by topic. Each organization operates within its own schedule for proposal evaluation and selection**.** Updates and notification timeframes will vary. If contacted regarding a proposal submission, it is not necessary to request information regarding additional submissions. Separate notifications are provided for each proposal.

It is anticipated all the proposals will be evaluated and selections finalized within approximately 90 calendar days of solicitation close. Please refrain from contacting the BAA COs for proposal status before that time.

Refer to the DoD STTR Program BAA for procedures to protest the Announcement.

As further prescribed in FAR 33.106(b), FAR 52.233-3, Protests after Award should be submitted to: Air Force SBIR/STTR BAA Contracting Officer Daniel Brewer, Daniel.Brewer.13@us.af.mil.

AIR FORCE SUBMISSION OF FINAL REPORTS

All final reports will be submitted to the awarding AF organization in accordance with the purchase order or contract. Companies will not submit Final Reports directly to the Defense Technical Information Center (DTIC).

PHASE II PROPOSAL SUBMISSIONS

AF organizations may request Phase II proposals while technical performance is on-going. This decision will be based on the contractor's technical progress, as determined by an AF TPOC's review using the DoD 22.B STTR BAA Phase I review criteria. All Phase I awardees will be provided an opportunity to submit a Phase II proposal unless the Phase I purchase order has been terminated for default or due to non-performance by the Phase I company.

Phase II is the demonstration of the technology found feasible in Phase I. Only Phase I awardees are eligible to submit a Phase II proposal. All Phase I awardees will be sent a notification with the Phase II proposal submittal date and detailed Phase II proposal preparation instructions. If the physical or email addresses or firm points of contact have changed since submission of the Phase I proposal, correct information shall be sent to the AF SBIR/STTR One Help Desk as instructed on A-1. Phase II dollar values, performance periods, and proposal content will be specified in the Phase II request for proposal.

NOTE: AF primarily awards Phase I and II contracts as Firm Fixed Price. However, awardees are strongly urged to work toward a Defense Contract Audit Agency (DCAA) approved accounting system. If the company intends to continue work with the DoD, an approved accounting system will allow for competition in a broader array of acquisition opportunities. Please address questions to the Phase II CO, if selected for award.

All proposals must be submitted electronically via DSIP by the date indicated in the Phase II request for proposal. Note: Only ONE Phase II proposal may be submitted for each Phase I award.

AIR FORCE STTR PROGRAM MANAGEMENT IMPROVEMENTS

The AF reserves the right to modify the Phase II submission requirements. Should the requirements change, all Phase I awardees will be notified. The Air Force also reserves the right to change any administrative procedures at any time to improve management of the AF STTR Program.

AIR FORCE 22.B STTR Phase I Topic Index

AF NUMBER: AF22B-T001

TITLE: Co Orbital Threat Prediction and Assessment

TECH FOCUS AREAS: Network Command, Control and Communications; Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Space Platform; Battlespace

OBJECTIVE: Develop methods for anticipating adversary spacecraft Courses of Action (CoAs) that differentiate between threat types; address finite burn, continuous thrust, and impulsive maneuvers; and encompass three body dynamics for beyond GEO objects.

DESCRIPTION: Battlespace awareness within the space domain is a critical foundation for planning appropriate courses of action, responding to threats, protecting vulnerable assets, and preparing contingency plans. The ability to maintain flexible deterrent options in various situations relies upon maintaining an accurate picture of (1) what is happening now, and (2) what could happen in the future. Because the set of future possibilities is infinite, it is important to broadly characterize these possibilities, and to best understand those which require a response or present the greatest threats to our assets and affect the service they provide. Classifying threats' possible actions, the object's subsequent trajectory, and what threats it can pose from along that trajectory are critical to maintaining object custody and awareness.

PHASE I: Identify potential solutions that enables prediction and characterization of co-orbital threats, and effectively manage the large set of future possibilities. Evaluate the solutions' feasibility and tractability for use in an operational environment. Compare performance and computation time for the investigated solutions. Proposed solutions should address finite burn, continuous thrust, and impulsive maneuvers, differentiate between kinetic and non-kinetic threats, and address three body dynamics for beyond GEO objects.

PHASE II: Develop prototype software that enables prediction and characterization of co-orbitals threats and manages the large number of future possibilities in a manner that is digestible and actionable for the user. Generate simulated threat trajectories and observations for threats in all orbital regimes with both continuous and impulsive thrust maneuvers. Demonstrate prototype capabilities by processing the simulated data. Display predicted courses of action and Indications and Warnings (I&W) in a prototype user interface with basic data visualization. GFE is not anticipated.

PHASE III DUAL USE APPLICATIONS: Develop prototype software that enables prediction and characterization of co-orbitals threats and manages the large number of future possibilities in a manner that is digestible and actionable for the user. Generate simulated threat trajectories and observations for threats in all orbital regimes with both continuous and impulsive thrust maneuvers. Demonstrate prototype capabilities by processing the simulated data. Display predicted courses of action and Indications and Warnings (I&W) in a prototype user interface with basic data visualization. GFE is not anticipated.

NOTES: The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the proposed tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the Air Force SBIR/STTR HelpDesk: usaf.team@afsbirsttr.us

REFERENCES: [1] The Aerospace Corporation, "Space Threat Assessment 2021," 2021. [2] S. M. Brown, "Knowledge Acquisition for Adversary Course of Action Prediction Models," AAAI Technical Report FS-02-05, 2002. [3] E. J. Santos, D. Li, E. E. Santos and J. Korah, "Temporal Bayesian Knowledge Bases - Reasoning About Uncertainty with Temporal Constraints," Expert Systems with Applications, vol. 39, no. 17, pp. 12905-12917, 2012.

KEYWORDS: Indications and Warning; Orbit Determination; Data Science; Course of Action Prediction; Threat Identification; Threat Characterization SS Radio Occultation; LEO; Hypersonics

TPOC: Carolyn Sheaff, Carolyn.Sheaff@us.af.mil, 315-330-7147

AF NUMBER: AF22B-T002

TITLE: Improved Integrated Circuit based Electricity to Radio Frequency Conversion Efficiency Development for Space based Applications

TECH FOCUS AREAS: Microelectronics; Directed Energy; 5G

TECHNOLOGY AREAS: Electronics; Space Platform; Materials; Information Systems; Air Platform; Battlespace

OBJECTIVE: The research team selected for this STTR award will be tasked with developing robust, compact, low cost, and easy to manufacture Radio Frequency Integrated Circuits (RFICs) that can efficiently convert a steady supply of electrical energy into a stable high power RF signal for power beaming applications. Robustness will be measured as the extent the RFICs developed by the STTR awardee can operate a high temperatures, at low temperatures, are tolerant of large temperature swings, can tolerate the hostile conditions found in an orbital environment, and the extent the RFICs developed are resistant to degradation as a function of operation time. Compactness well be measured as a function of how many RFICs can be established on a fixed panel given a specific mass and volume limit. Low cost and easy to manufacture will be measured as the extent the RFICs developed by the STTR awardee can be made with low cost materials and are amenable to being manufactured using standard high throughput integrated circuit (IC) production techniques. High efficiency will be assessed as the extent the RFICs developed by the STTR awardee can exceed the performance of state of the art mass produced RFICs; specifically, the DC-to-RF conversion efficiency of the RFICs developed should be greater than 40% when, either acting independently or in concert with a collection of RFICS, broadcasting at least 200W of RF power. High power RF broadcast stability will be measured as a function of the maximum RF power a RFIC can output, the extent a single or array of RFICs can provide a constant RF signal with a specific waveform, and the duration a RFIC can continuously output RF energy.

DESCRIPTION: This STTR call seeks to combine the academic prowess of a university and the commercial expertise of a small business to develop new Radio Frequency Integrated Circuit (RFIC) design paradigms to efficiently generate Radio Frequency (RF) energy for space based power beaming applications. Solid state RF devices are sought as it has been shown that they can be compact, lightweight, and extreme temperature tolerant components that can be designed to generate large amounts of RF power when reasonable amounts of voltage or electric current is applied. To support efforts to develop space based power beaming capabilities, the RFICs developed by this STTR will need to be suitable for deployment on space platforms, capable of producing stable waveforms, can be used to create a high power signal, require limited voltage to operate, have long operational lifetimes, are easy to integrate into existing space systems, and can be mass produced at low cost. Proposals sought in this STTR will detail how their planned work will create RFICs that will outperform current state of the art RFICs by utilizing new designs, address challenges with creating a space systems, and enable successful designs to be manufactured easily. Of particular interest will be discussions on how the new RFICs the proposers plan to develop can be used to create high power RF beams with desired waveforms given the limited amount of electrical power available to be expended on spacecraft, how the proposed designs will mitigate undesired energy losses, why the proposed designs are anticipated to be robust enough to be used on a long duration space mission, and why it anticipated that the proposed RFIC design the proposers plan to develop will easy to manufacture.

PHASE I: By the conclusion of their Phase I effort, the STTR awardee will be expected to have completed a laboratory demonstration that proves their RFIC design can generate an RF signal with a reasonable electrical power to RF power conversion efficiency.

PHASE II: By the conclusion of a Phase II effort, the STTR awardee will be expected to have prepared RFICs, working either independently or in collectively, capable of generating a stable RF signal. This RF signal should have a desirable RF waveform and be emitted at a strength greater than 200W.

PHASE III DUAL USE APPLICATIONS: By the conclusions of a Phase III effort, approaches to package promising RFICs developed by this STTR will have been discovered that will enable these RFICs to be easily integrated into electronic systems. Additionally, ways to mass produce promising RFICs developed by this STTR will also have been identified.

NOTES: The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the proposed tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the Air Force SBIR/STTR HelpDesk: usaf.team@afsbirsttr.us

REFERENCES: References Sato, D. et al., “Thermal Design of Photovoltaic/Microwave Conversion Hybrid Panel for Space Solar Power System”, IEEE Journal of Photovoltaics, 7, 1, 2017, pp. 374-382; Jaffe, P. et al., “Sandwich module prototype progress for space solar power”, Acta Astronautica, 94, 2014, pp. 662–671; Jaffe P. et al., "Energy Conversion and Transmission Modules for Space Solar Power," in Proceedings of the IEEE, 101, 6, 2013, pp. 1424-1437; H. Ikeda et al. "Power conversion efficiency in DC-to-RF MOS-FET high power inverter operating at 2.5 MHz," 1991., IEEE International Symposium on Circuits and Systems, 1991, pp. 3035-3038 vol.5.

KEYWORDS: RF; RFIC; Radio Frequency Integrated Circuit; DC to RF; power beaming; directed energy; RF generation; space; spacecraft; satellite

TPOC: Thomas Peng, thomas.peng.3@us.af.mil, (505) 846-4524

AF NUMBER: AF22B-T003

TITLE: Variable Emissivity Thermal Control Capability Development for Space based Applications

TECH FOCUS AREAS: Quantum Sciences

TECHNOLOGY AREAS: Space Platform; Materials

OBJECTIVE: The goal of this STTR is to create a variable emissivity thermal control device or coating that can adopt at least two states that differ in emissivity by at least 0.5 and can either adopt either a very low emissivity state, specifically a state with less than 0.1 emissivity, or a very high emissivity state, specifically a state with an emissivity greater than 0.9, that is robust enough to tolerate extended use on an orbital platform. The emissivity change of this device should be triggered either by input from an external user or by a change in temperature. User input triggered variable emissivity devices should have low Size, Weight, and Power (SWAP) requirements and be easy to use and integrate existing systems. Temperature triggered variable emissivity coatings or devices should adopt a high emissivity state the system it is thermally regulating is hot and a low emissivity state when this system is cold.

DESCRIPTION: Keeping an orbital asset at an optimal operating temperature can be extremely challenging as orbiting spacecraft experience large temperature swings as the extent it is illuminated by the Sun changes as it enters and leaves eclipse, the difficulty in getting hardware into space, the limited amount of volume available on spacecraft, the limited amount of power available on spacecraft, and the restriction that any heat that is released from a spacecraft must leave radiatively as spacecraft operate in a vacuum. To alleviate thermal control challenges, this STTR seek to combine the academic expertise of universities and the product development expertise of small businesses to develop space tolerant variable emissivity devices or coatings that can radiatively release heat from a spacecraft when it becomes too hot and curtail the heat released from a spacecraft when it is too cold. As a technology to support spacecraft operations, the variable emissivity technology sought by this STTR should provide good thermal control, have low Size, Weight, And Power (SWAP) requirements, be robust enough to tolerate the hostile conditions found in orbit, is easy to use, and is simple to incorporate into existing spacecraft designs. The degree of thermal control the technology can provided will be assessed by the maximum emissivity the technology can establish, the minimum emissivity the technology can establish, the total change in emissivity the technology can provide, and the extent the technology can establish the optimal emissivity when the spacecraft is at different temperatures. Overall SWAP will be considered as the amount of mass, volume, and power needed to install and operate the system. Robustness will be assessed as the extent the device or coating can tolerate temperature cycling and endure extended exposure to high energy photons and charged particles found in space. Ease of use will be measured by how difficult it is to get the variable emissivity technology to adopt the desired emissivity and how few reasonably probable ways the variable emissivity technology can fail can be identified. Finally, amenability to integration into existing spacecraft designs will be assessed by extent the form of the variable emissivity technology developed by this STTR can be tailored to accommodate different spacecraft architectures. The proposals sought for this STTR will present an innovative new approach to create a variable emissivity device thermal control device or detail a convincing plan to improve the performance of approaches explored in the past. If an innovative new approach is proposed, it would be useful if the proposer articulated why this new approach is promising. If the proposed approach utilizes some form of reversible electroplating, it would be useful if the proposers provided discussion on how they plan to overcome limitations with the low IR transparency of electrical conductors. If the proposed approach utilizes oxidation changes or charge migration, it would be useful if the proposers discuss why their approach is still anticipated to function when exposed to the charged particle and radiation environment found in space. If the proposed approach utilizes a phase change, it would be useful if the proposers articulate why they believe their proposed approach will tolerate repeated cycling between a high and low emissivity configuration. With any approach presented, it is important for the proposers to detail why they believe their proposed approach will be able to provide the desired thermal control and why they believe their proposed approach will be suitable for extended use on an orbital asset.

PHASE I: Complete a laboratory demonstration of a variable emissivity device that can adopt a high emissivity state when hot and a low emissivity state when cold.

PHASE II: Prepare a robust variable emissivity thermal device or coating that can provide at least 0.5 emissivity change, can adopt an emissivity state above 0.8 or below 0.2, and is packaged in such a way that it can be deployed to space where its performance while on orbit can be assessed.

PHASE III DUAL USE APPLICATIONS:

NOTES: The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the proposed tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the Air Force SBIR/STTR HelpDesk: usaf.team@afsbirsttr.us

REFERENCES: Wu, X et al., “Passive Smart Thermal Control Coatings Incorporating CaF2/VO2 Core−Shell Microsphere Structures”, Nano Lett. 2021, 21, pp. 3908-3914; Athanasopoulos, N. et al., “Variable emissivity through multilayer patterned surfaces for passive thermal control: preliminary thermal design of a nano-satellite”, 48th International Conference on Environmental Systems, 8-12 July 2018, Albuquerque, New Mexico; Vlassov, V. V. et al., “Analysis of Concept Feasibility and Results of Numerical Simulation of a Two-Stage Space RadiatorWith Variable Emissivity Coating”, Heat Transfer Engineering 2017, 38, 10, pp. 963-974; Vlassov, V.V. et al., “New Concept of Space Radiator with Variable Emittance”, J. of the Braz. Soc. Of Mech. Sci. & Eng. 2010, 32, 4, pp. 400-408; Darrin, A.G. et al., "Variable emissivity through MEMS technology," ITHERM 2000. The Seventh Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (Cat. No.00CH37069), 2000, pp. 264-270

KEYWORDS: Variable emissivity; thermal control; reversible electroplating; phase change; electrochromic; smart windows; functional paint; space; spacecraft

TPOC: Thomas Peng, thomas.peng.3@us.af.mil, (505) 846-4524

AF NUMBER: AF22B-T004

TITLE: Collaboration of Humans and Autonomy Research Teaming Testbed (CHART2)

TECH FOCUS AREAS: Network Command, Control and Communications; Autonomy

TECHNOLOGY AREAS: Ground Sea; Space Platform; Information Systems; Air Platform

OBJECTIVE: The objective of this topic is to develop a mid-fidelity stand-alone testbed for critical research on human-autonomy teaming concepts that uses command and control (C2) tasks relevant to Joint All Domain Command and Control (JADC2) missions (air, land, sea, cyber, and space). Ultimately, use of a mid-fidelity research testbed that enables quick turn research will inform design guidelines and interface components, minimizing long lead time and costly modifications to high-fidelity systems currently used to investigate and validate human-autonomy teaming for military operations.

DESCRIPTION: 711 HPW/RHWC 6.2 human-autonomy research has relied on a mix of low-fidelity software, mid-fidelity testbeds, and high-fidelity systems (example of the latter is the Intelligent Multi-UxV Planner with Adaptive Collaborative/Control Technologies [IMPACT]). [1] Although low-fidelity testing yields quick answers to interface concepts agnostic of mission requirements, testbeds provide a quick way to examine concepts within a representative mission environment without the lead time and software costs involved to modify a fully operational system such as IMPACT. A mid-fidelity testbed will be an essential research tool for evaluating new human-autonomy teaming solutions, given that more and more systems will include some form of intelligent aiding due to advancements in artificial intelligence that change the role and tasking of human operators. The “Collaboration of Humans and Autonomy Research Teaming Testbed” (CHART2) product of this effort will be a critical component for evaluating the effectiveness of candidate control and display technologies in providing support to human and autonomy JADC2 team members, in that current testbeds are inadequate. For example, a mid-fidelity testbed, Adaptive Levels of Autonomy (ALOA; SBIR product from the early 2000s [2]) has supported over a decade of experiments investigating system performance related to levels of automation that are, however, limited in their ability to support teaming with the human operator. There are newer teaming test environments that demonstrate modularity in human-autonomy teaming structures, generate scenarios for observing human interaction, and facilitate the measurement and analysis of responses. [3] However, these mid-fidelity testbeds, as well as the high-fidelity IMPACT system, are inadequate to enable quick-turn research investigating human-autonomy teaming that involves asset allocation/transfer, task allocation/sharing, and varying communication structures. Nor do they support tasks that are representative of those envisioned for future complex JADC2 missions. They are also not designed to simulate or support a range of robust and highly capable types of autonomy (e.g., that support vehicle operations, C2, and/or decision support tools for mission related tasks). Lastly, their autonomy components are less able to work as a teammate to the human operator in flexible communication and interaction structures, how and when humans and autonomous teammates update and share information or collaborate in a task, involving a variety of data streams in support of completing JADC2 relevant mission tasks. Thus, a stand-alone mid-fidelity testbed featuring simulated and/or real autonomy components is needed that supports research examining a variety of human-autonomy teaming/communication structures. This testbed should support representative JADC2 tasks, meaning missions that include task completion with UxV (Unmanned Vehicles), as well as at least satellite and cyber effects to collaboratively address tasks within the simulated environment. A variety of test protocols should also be supported by which the experimenter can specify which domain(s) are available for task completion, as well as which teaming protocols are in effect, how communication structures are configured, and the available candidate display/control interfaces for any given trial/mission. Moreover, the testbed needs to be modular to enable the experimenter to configure a variety of multi-domain scenarios such that tasks/their order/mission events/difficulty level, as well as the autonomy's capability/reliability/transparency can be specified across multiple experimental trials. Ideally, the tasks, although representative of envisioned JADC2 tasks, should be easily trained to enable a wide range of test participants (college students to DoD subject matter experts). With respect to completion of specific JADC2 related tasks/missions, the testbed should be designed such that the human-autonomy teaming can be dynamic and context dependent. The testbed should support assessment of team collaboration on task completion, in order to determine what teaming structures and station interfaces best support mutual visibility and directability across human-autonomy members, as well as enhance task performance, completion of mission objectives, and the human's situation awareness and appropriate trust in the autonomy. [4,5] Specifically, the CHART2 testbed should enable timely evaluation of the effectiveness of candidate controls and displays in establishing and updating working agreements that define each human-autonomy team member's responsibilities for completing JADC2 task related functions, as well as coordinate courses of action, communicate pertinent information, track task completion/system status, and support shared situation awareness. [6] The results from research using a human-autonomy teaming focused mid-fidelity CHART2 testbed in DoD laboratories will mature solutions and accelerate follow-on validation research in high-fidelity systems (e.g., IMPACT), as well as inform C2 interface requirements and decision support aids needed for eventual JADC2 military applications. For example, multiple quick turn experiments using the CHART2 testbed can narrow down specific symbology and needed level of detail on the autonomy's processing to effectively apply multiple domains for task completion. The product's mission context and tasks also have the potential to be reconfigured for human-autonomy teaming applications appropriate for multiple civilian and commercial domains (e.g. Air Traffic Control, Emergency Response coordination), as well as basic research to examine factors influencing human-autonomy teaming on task performance (e.g., human's personality/experience level/workload and autonomy support's timeliness, transparency, etc.).

PHASE I: Phase I will primarily focus on a) exploring the human autonomy teaming research space to determine what teaming concepts and interfaces will be supported and configurable in the testbed, b) identifying JADC2 tasks to represent within the testbed and relevant team performance metrics with easily exportable formatted data, and c) describing the proposed hardware/software developmental approach for implementing the testbed to best support a variety of teaming related experimental designs. For the latter, relevant features for experimenter control include, but are the limited to, selection of: available domains, number and types of tasks to be completed and resulting workload level, teaming structure (number of teammates, responsibility of teammates, etc.), features of controls and displays by which the human-autonomy team members interact, capability/transparency/reliability of the autonomy, and objective and subjective participant data to record and analyze.

PHASE II: Develop and demonstrate a prototype testbed with the human-autonomy teaming concepts and JADC2 representative tasks identified in Phase I. This demonstrative testing should focus specifically on: 1. The choices for manipulated teaming structures. 2. Validated measures collectable using the testbed and their exportability 3. How the solution can be sustainable and scalable to the needs of researchers. Other specific DoD or governmental customers who express interest in using the product should also be identified.

PHASE III DUAL USE APPLICATIONS: The software development practices employed against this topic will inform research testbed designs for a variety of human and autonomy teaming applications, both commercial and government. Additionally, with modifications, the testbed could be reconfigured to support research examining human-autonomy teaming in support of related civilian applications.

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KEYWORDS: Human Autonomy Teaming; Teaming; Testbed; Test console; Tasks; Automation; Human AI teaming; Human Agent Teaming

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AF NUMBER: AF22B-T005

TITLE: Complex Emitter Behavioral Analysis Using Machine Learning

TECH FOCUS AREAS: Autonomy; Artificial Intelligence/Machine Learning

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Given sequences of observations of unknown radar waveforms, develop behavioral models to enable inference of radar intent and threat level, and to enable prediction of future behaviors. These models should generalize to arbitrary emitters without a priori knowledge.

DESCRIPTION: The proliferation of low cost, high performance computing hardware has enabled the development of increasingly complex radar systems. The agility and modularity of these new threats force electronic support (ES) systems to operate against a much wider threat parameter space where it is impossible to capture every radar system variant in a mission data file (MDF). Numerous techniques have been proposed to address the recognition of known agile multifunction radar systems [1] [2] [3] [4], and many methods for recognizing unknown observations have been proposed in the machine learning literature [5]. However, very few publications consider making useful inferences against unknown radar systems [6] [7]. An accurate understanding of the threat landscape is important when selecting and optimizing an electronic countermeasure response. Therefore, handling unknown signals remains an urgent challenge for ES systems. If no MDF match for an observed signal is found, the observation is labeled as an unknown. Given a sequence of these observations over time, a range of useful inferences could be made, including the radar's intent (e.g. search vs. track) and threat level to the ES host platform. The main objective of this effort is to use statistical modeling and machine learning techniques to construct behavioral models for these unknown radar waveforms to track and predict behaviors over time. Developing such models requires consideration of several questions. What features are needed to construct effective behavior models? Traditional pulse descriptor words (PDWs) containing pulse time of arrival, frequency, pulse width, and amplitude have historically provided enough information for single pulse characterization and emitter identification. However, given the increased complexity of agile multifunction radars, it might be necessary to consider additional features at different timescales. How can we best apply tools from statistics and machine learning to form behavior models? As this effort considers unknown waveforms with no a priori (MDF) knowledge, such a model should be generalizable to a wide range of potential threats. Once a behavior model has been fit to a sequence of observations, how can these behaviors be associated with varying levels of threat? For instance, the behavior model might indicate that the radar is deploying tracking modes. Based on this knowledge, and considering other factors such as inferred distance to the threat, the ES system should infer an appropriate threat level. Given a time history of behaviors, can the model be used to predict future behaviors? Predictive inference could reduce the reaction time of electronic warfare systems, reducing the time required to select and deploy electronic countermeasures. The contractor will develop and evaluate a software prototype of the proposed modeling technique. The software prototype will need to be written to interface with the government-owned Advanced Research Concepts for Electronic Measures (ARCEM) test and evaluation framework to enable the government to conduct in-house verification testing. ARCEM provides the technical pipeline – technology maturation and staging – between AFRL and the 350th Spectrum Warfare Wing, which can be utilized for spiral transition of promising technologies. The government will provide data for the contractor to use in evaluating the developed behavior models, and will provide interface control documents for the ARCEM architecture. No other government materials, equipment, or facilities are required to successfully address this topic.

PHASE I: Conduct a study to evaluate the feasibility of the proposed solution (referencing (1) – (4) above). Phase I should document the proposed approach to behavior modeling, complete with a discussion of the assumptions made, limitations of the selected modeling approach, and a plan to demonstrate the model effectiveness given government furnished data with proposed performance metrics. The government will provide interface control documents for the ARCEM architecture to enable the contractor to plan their phase II implementation accordingly.

PHASE II: Develop and demonstrate prototype determined to be the most feasible solution during the Phase I study using government furnished data. Deliver ARCEM-compliant prototype source code and final report detailing the theory, implementation, and quantitative performance of the prototype.

PHASE III DUAL USE APPLICATIONS: The emitter agnostic behavior modeling described in this topic supports the vision of cognitive electronic warfare by enabling the host platform to make useful inferences about unknown emissions and formulate appropriate responses. Commercial applications include spectrum sharing and dynamic spectrum access, where predicting the behavior of primary users could enable a secondary user to rapidly maneuver to mitigate interference to primary users.

NOTES: The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the proposed tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the Announcement and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the Air Force SBIR/STTR HelpDesk: usaf.team@afsbirsttr.us

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KEYWORDS: Software defined radar; Cognitive electronic warfare; Radar intent inference; Behavior modeling; Probability and statistics; Machine learning

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AF NUMBER: AF22B-T006

TITLE: Self-Regulating Heaters for Satellites

TECH FOCUS AREAS: Autonomy

TECHNOLOGY AREAS: Space Platform

OBJECTIVE: Develop and commercialize self-regulating (positive temperature coefficient, PTC) heaters for use on satellites in any earth orbit.

DESCRIPTION: Self-regulating heaters are heaters with a designed-in temperature setpoint that exists as a property of the resistor material. They are 'smart' heaters, automatically and independently warming each region of the heater circuit to the designed setpoint without a temperature sensor. The electrical resistance of the heater material jumps substantially at the setpoint, inhibiting electric flow and production of heat above the setpoint temperature. Self-regulating heaters are in use in the petrochemical and automotive industries for pipe freeze protection and seat warmers. The space industry needs self-regulating heaters for propellant system heaters where allowable temperature ranges are tight and thermal environments vary in both time and space. Conventional solutions to propellant system thermal control are resource intensive, requiring much engineering design and touch labor as well as much hardware and burdening the flight computer to control the circuits. Self-regulating heaters reduce all of these resource demands. Self-regulating heaters can also provide similar benefits for other satellite heaters such as those for batteries, mechanisms, and antennas. Existing self-regulating heaters are not suited for space applications for several reasons: 1) the form factor is too large and inflexible: existing self-regulating heaters are a stiff cable while satellite self-regulating heaters must be a thin-film heater such as adhesively-applied polyimide heaters commonly used on satellites. Additionally, these heaters must be suitable to install on two orthogonal bend axes: a 1/8" bend radius and a 3" bend radius, 2) existing self-regulating heaters provide their resistance transition via a melt expansion process to break the percolating path; this means that existing self-regulating heaters cannot be exposed to temperatures greater than their setpoint temperature, 3) Existing self-regulating heaters are not designed to handle the space environment; specifically: vacuum, ionizing radiation, and wide thermal cycles. This topic solicits proposals to develop and commercialize self-regulating heaters for space applications that address these aforementioned insufficiencies of existing self-regulating heaters. Additionally, the materials design must be capable of tuning during manufacturing of the material for setpoint temperatures between -5 and 20 C. A 30:1 (threshold) and 100:1 (objective) turndown ratio between the electrical resistances above and below the setpoint temperature must be achieved. The technology must be capable of yielding designs operating with any voltage between 12 and 100 VDC, and must be capable of producing designs yielding 1 to 10 W/in2 heat flux at the fully ON condition. Capable to withstand exposure to environments in all of the following orbits: 5 years in low earth orbit (LEO), 10 years in middle earth orbit (MEO), or 15 years in geosynchronous earth orbit (GEO) including vacuum, ionizing radiation, and thermal cycling. Radiation environments should assume the technology receives 40 mils of spacecraft Aluminum shielding (threshold) or no additional shielding (objective); radiation shields incorporated in the heater will be considered but radiation-hardened heater materials are strongly preferred. Thermal cycles between -5 and 40 C, with LEO 60k cycles, MEO 15k cycles, and GEO 6k cycles. Also survive up to 10 thermal cycles from -40 to 70 C. The material should always remain a solid. The manufacturing process should be scalable, e.g. screen printing techniques; the installation process should minimize touch labor. Proposers must demonstrate a strong intent and capability to commercialize the technology. Proposers are strongly encouraged to form teams with manufacturing partners and systems integrators for technology transition.

PHASE I: Build and test the performance of hardware. Demonstrate by analysis and/or test the feasibility of the concept to meet all requirements.

PHASE II: Further develop manufacturability of hardware. Test environmental capability of the hardware. The culmination of the Phase II effort shall include the hardware delivery of 10 functional, tested self-regulating heaters demonstrating a variety of sizes and mounting configurations.

PHASE III DUAL USE APPLICATIONS: Design, build, deliver, and support an experiment to allow the USSF to demonstrate the technology in a combined effects environment.

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KEYWORDS: Resilience; Directed Energy Threat; DE threat; hardware

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